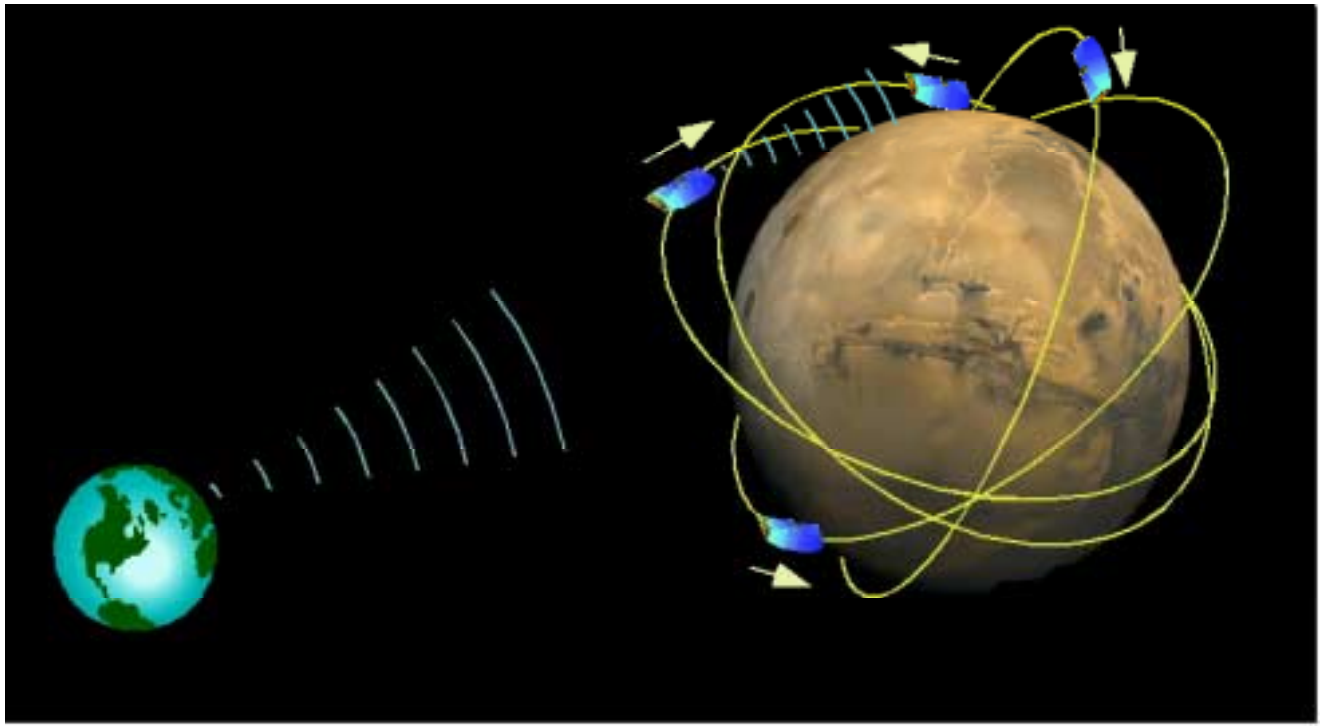
Science Missions Utilizing Microwave Beacon Microsatellites



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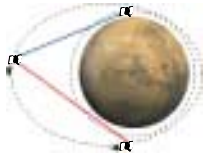
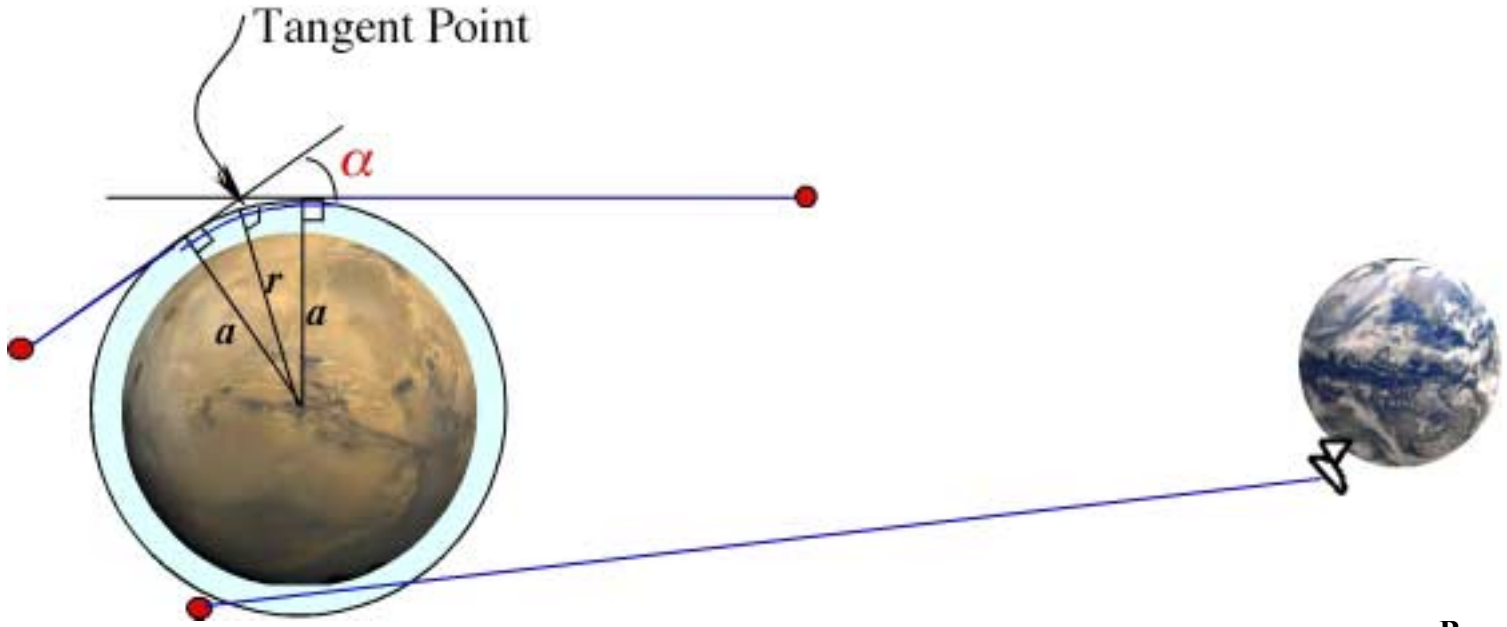
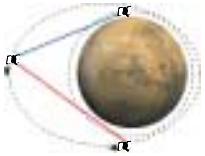
5 April 2002



Radio Occultation Measurements

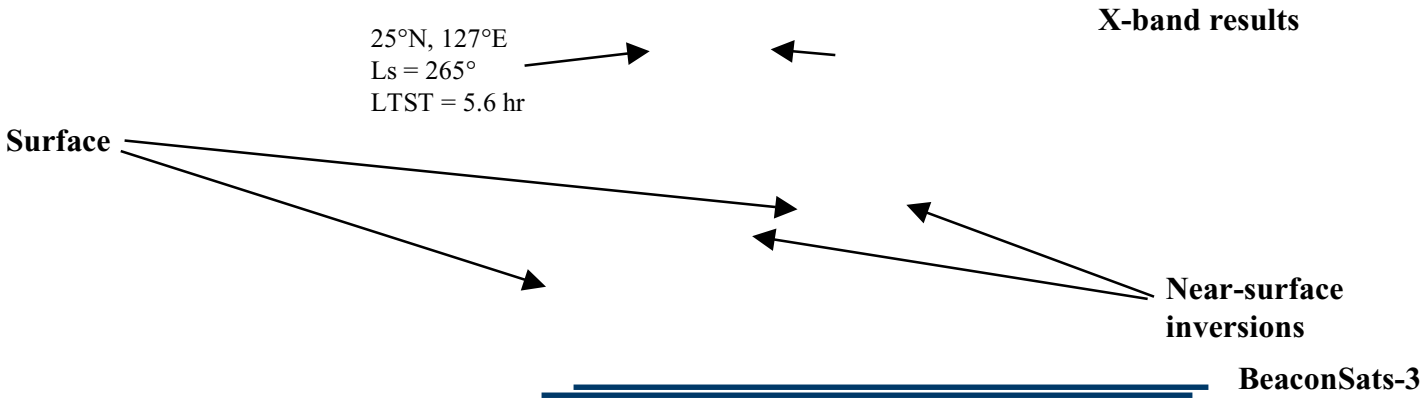
- **Measurements of radio signal between spacecraft during occultations (rising or setting) provide high-accuracy, high-resolution atmospheric measurements**
  - **Doppler shift yields refractivity, CO_2 density, pressure and temperature profiles**
  - **Attenuation of signal at constituent absorption lines yields constituent density profile (e.g. H_2O)**

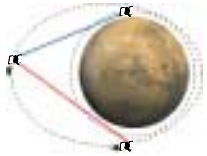




Radio Occultation Accuracy and Resolution

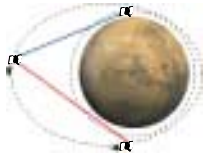
- **Measure atmospheric water concentration and relative humidity with high accuracy and 0.1-0.25 km vertical resolution**
- **Measure temperature to sub-Kelvin accuracy with 0.1-0.5 km vertical resolution**
- **Measure CO_2 density and therefore bulk pressure versus height with 0.1% accuracy and 0.1-0.5 km vertical resolution**





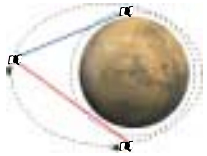
Occultation Mission Overview

- Satellite microwave occultations characterize the atmosphere with
  - very high vertical resolution
  - accuracy
  - in clear or cloudy conditions
- Satellite to satellite occultations provide global coverage for climate and weather observations including diurnal coverage
- Atmospheric profiles of
  - Temperature and pressure versus height
  - Constituents: H_2O, O_3, HDO, CO_2 (on Mars)
  - Winds (indirectly)
- Global coverage requires at least 2 satellites in high inclinations, one carrying a transmitter and the other carrying a receiver
- Mars Atmospheric Constellation Observatory is Mars Scout mission concept built around microwave satellite to satellite occultations



Occultations with Beacon Satellites

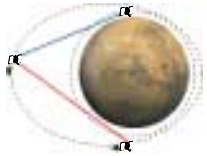
- **Deploying beacon satellites would provide extra occultation signal sources**
- **X-band signals are obvious choice for Mars**
  - **Compatible with spacecraft telecom design and DSN**
  - **Readily available components**
- **Each occultation would profile**
  - **CO_2 density, pressure, and temperature**
  - **Winds (indirectly through horizontal pressure gradient)**
- **With 1 W radiated power and omni-directional antenna could produce occultations with**
  - **Very high accuracy**
  - **1 km vertical resolution**
  - **From surface to 50 km altitude**



Minimal characteristics of beacon satellite

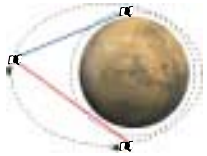
- Omni-directional microwave antenna
- X-band amplifier (~1 W RF out)
- X-band Exciter
- Ultra Stable Oscillator
- Power system
  - Solar panels (body mounted)
  - Battery (USO must be powered during eclipses)
  - Switch on at orbital deployment
- Structure
  - Cube ~0.5 m across (to meet power requirements)

- NO attitude control system
- NO telemetry or commanding systems



Number of satellites

- Satellite to satellite occultation missions are limited in their sampling density by the number of satellites
- More occultations would provide better coverage and improve
  - Characterization of weather related phenomena
  - Regional coverage
  - Wind estimates
- Increasing number of occultations requires more satellites
  - Satellites provide both the signal sources and the receivers
- Beacons offer an inexpensive enhancement
  - Beacons provide additional signal sources to increase the number of occultation profiles

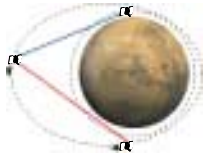


Occultations vs. number of beacons

- **With two satellites with full transmit and receive capability**
  - **2 satellites: 4 occ/orbit**

- **And we add beacon satellites**
  - **Add 4 occ/orbit per MACO satellite - beacon pair**

# of beacons	Additional Occ/orbit
1	8
2	16
3	24

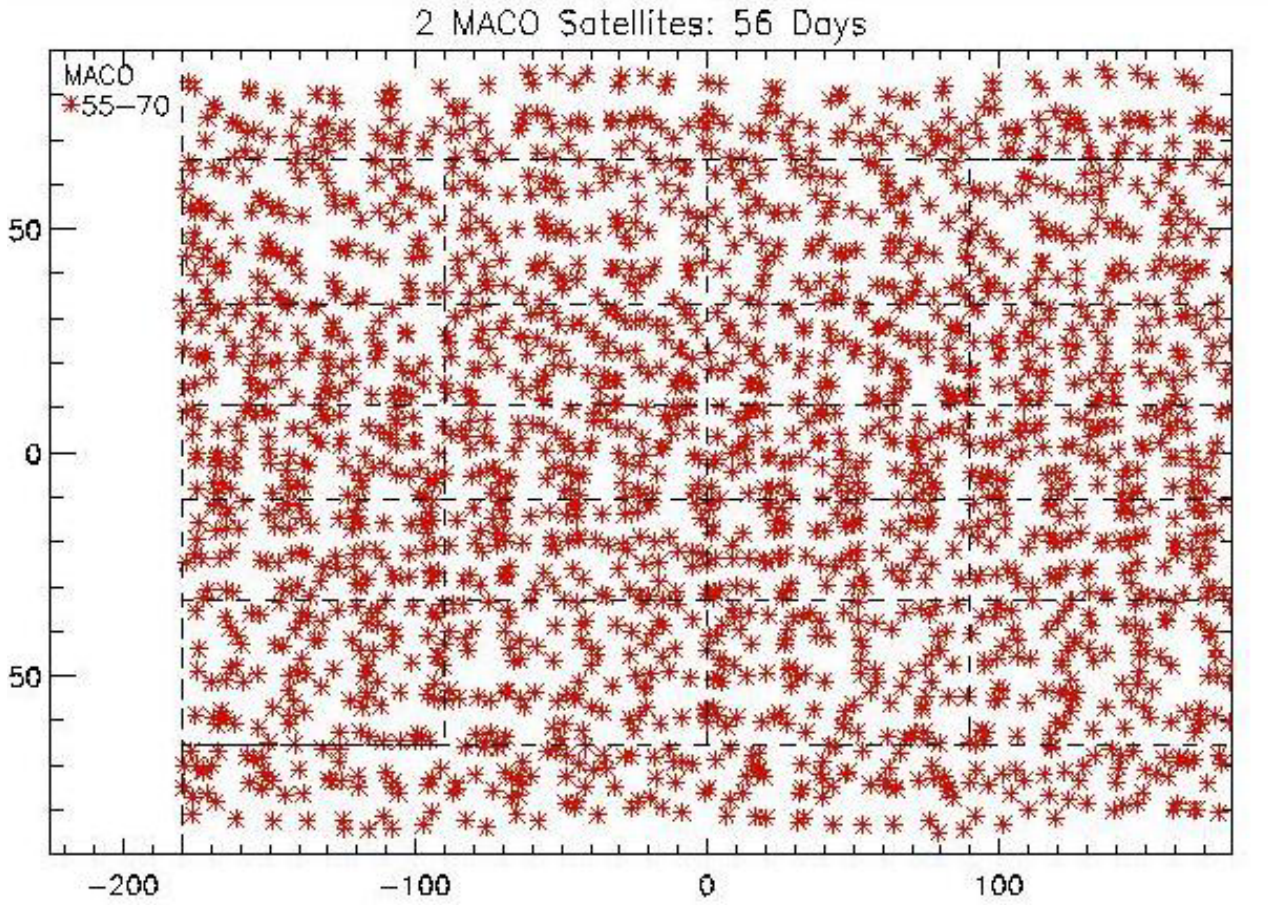


How many satellites does MACO need?

- **Principal science coverage objectives:**
  - **Global coverage**
  - **Full sampling of diurnal cycle within a Martian month by region**
  - **Wind coverage**
- **Global and diurnal coverage can be achieved well with minimum two-satellite constellation**
  - **A third satellites doubles or triples the coverage depending on its orbit**
- **Wind coverage is substantially better with three-satellite constellation**
  - **Can be achieved with 2 full satellites plus beacon**

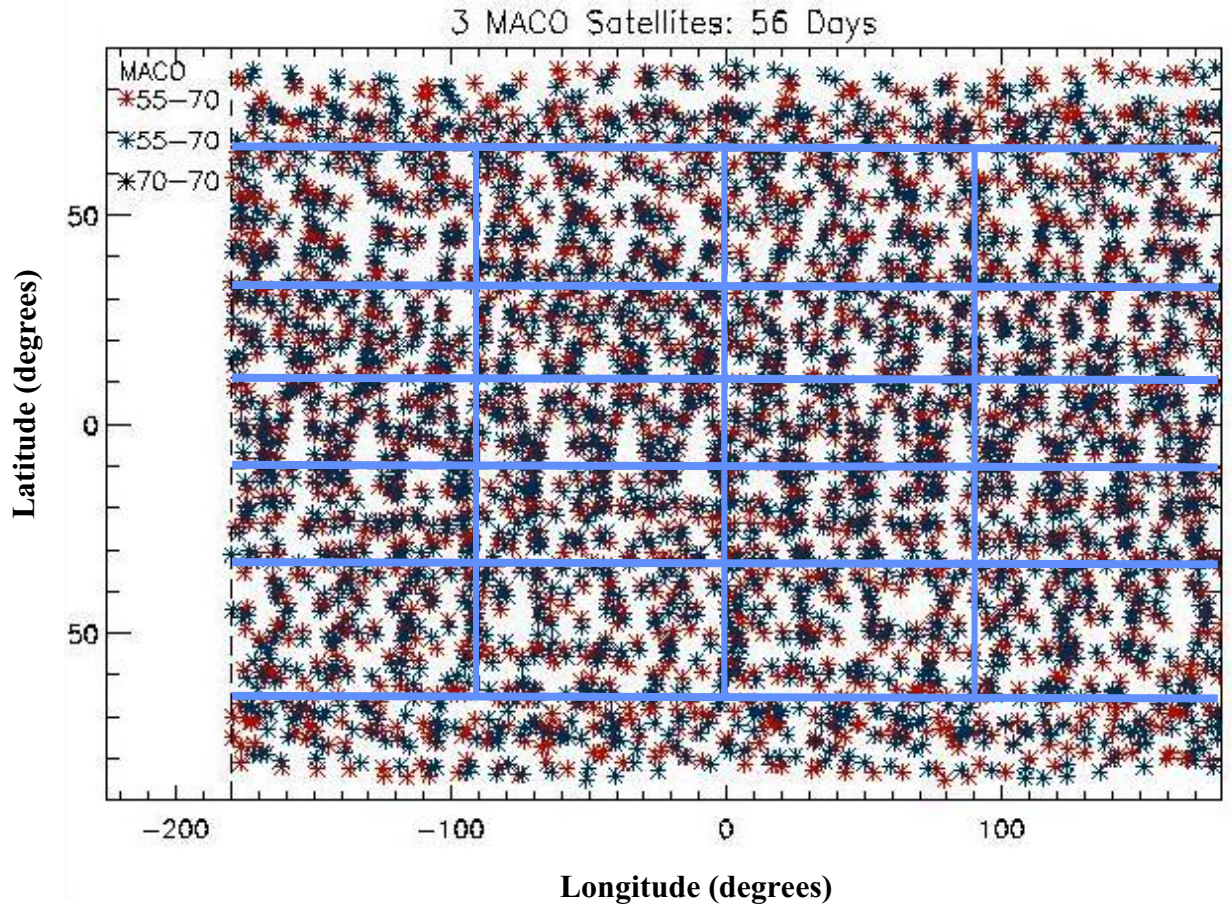
Global Coverage

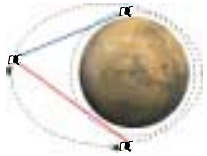
- **2 satellites yield more than 2000 globally distributed occultations in a Martian month**



Global Coverage

- **Three satellites yield more than 4000 globally distributed occultations each Martian month**



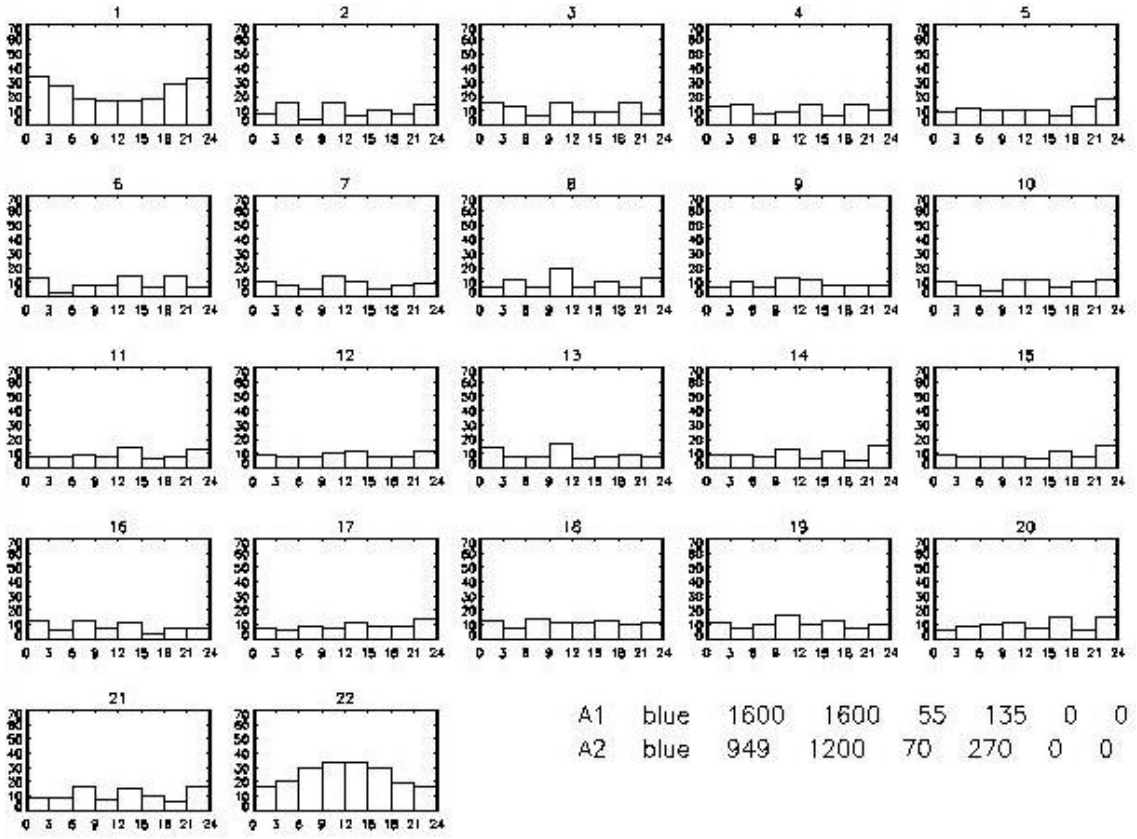


Diurnal Coverage

- **Objective is characterization of diurnal cycle and exchange between surface and atmosphere**
- **Requires sampling the entire diurnal cycle over small fraction of annual cycle**
- **As our goal, chose to sample diurnal cycle regionally over a Martian month (55 days)**

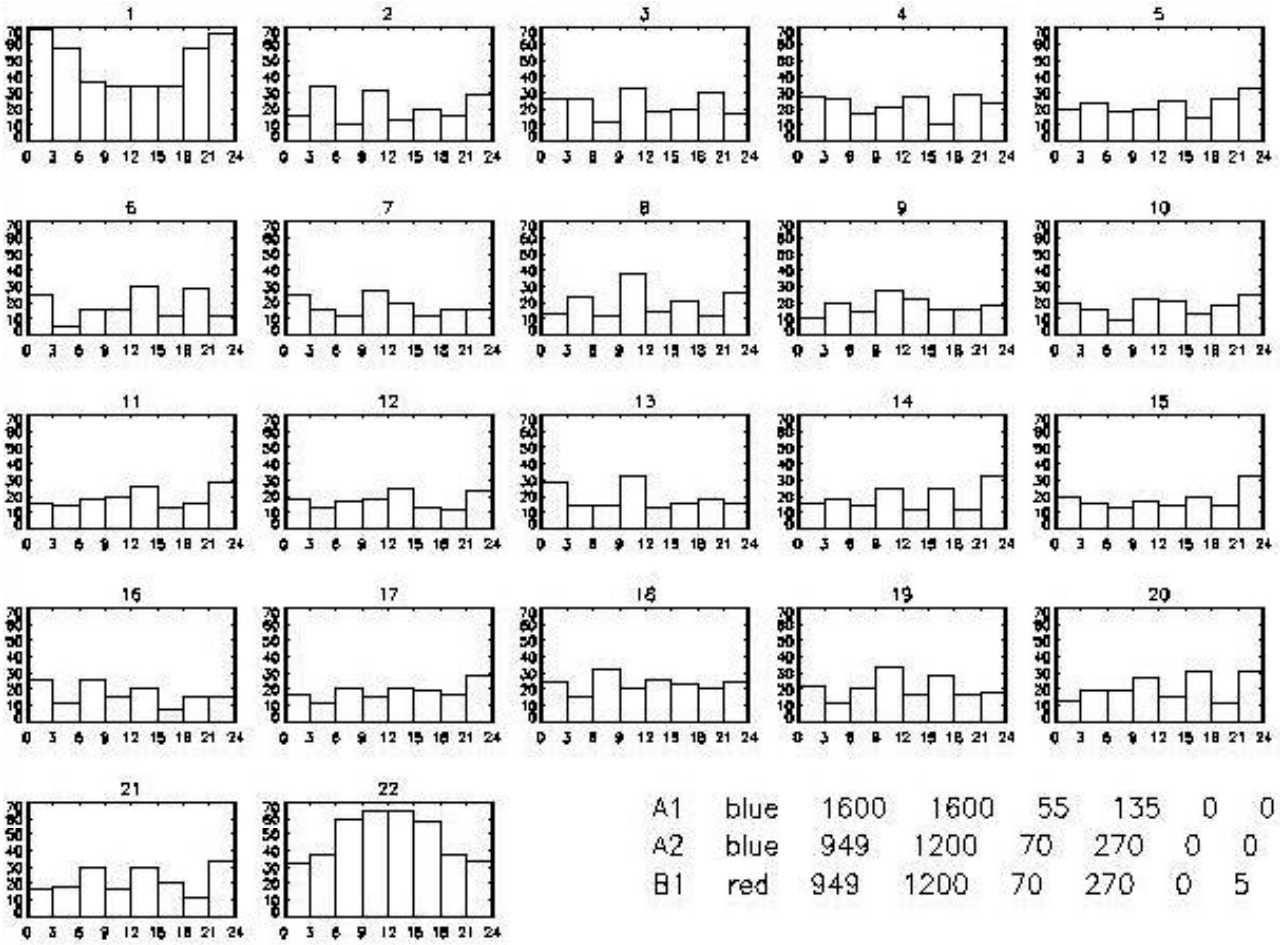
Diurnal Coverage with Two Satellites

- **Average 11 occultations in each of 3 hour bins over 22 regions over 55 days with 2 satellites**

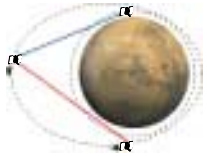


Diurnal Coverage with 2 Satellites + Beacon

- **Average 22 occultations in each of 3 hour bins over 22 regions over 55 days with 2 satellites plus beacon**



A1	blue	1600	1600	55	135	0	0
A2	blue	949	1200	70	270	0	0
B1	red	949	1200	70	270	0	5



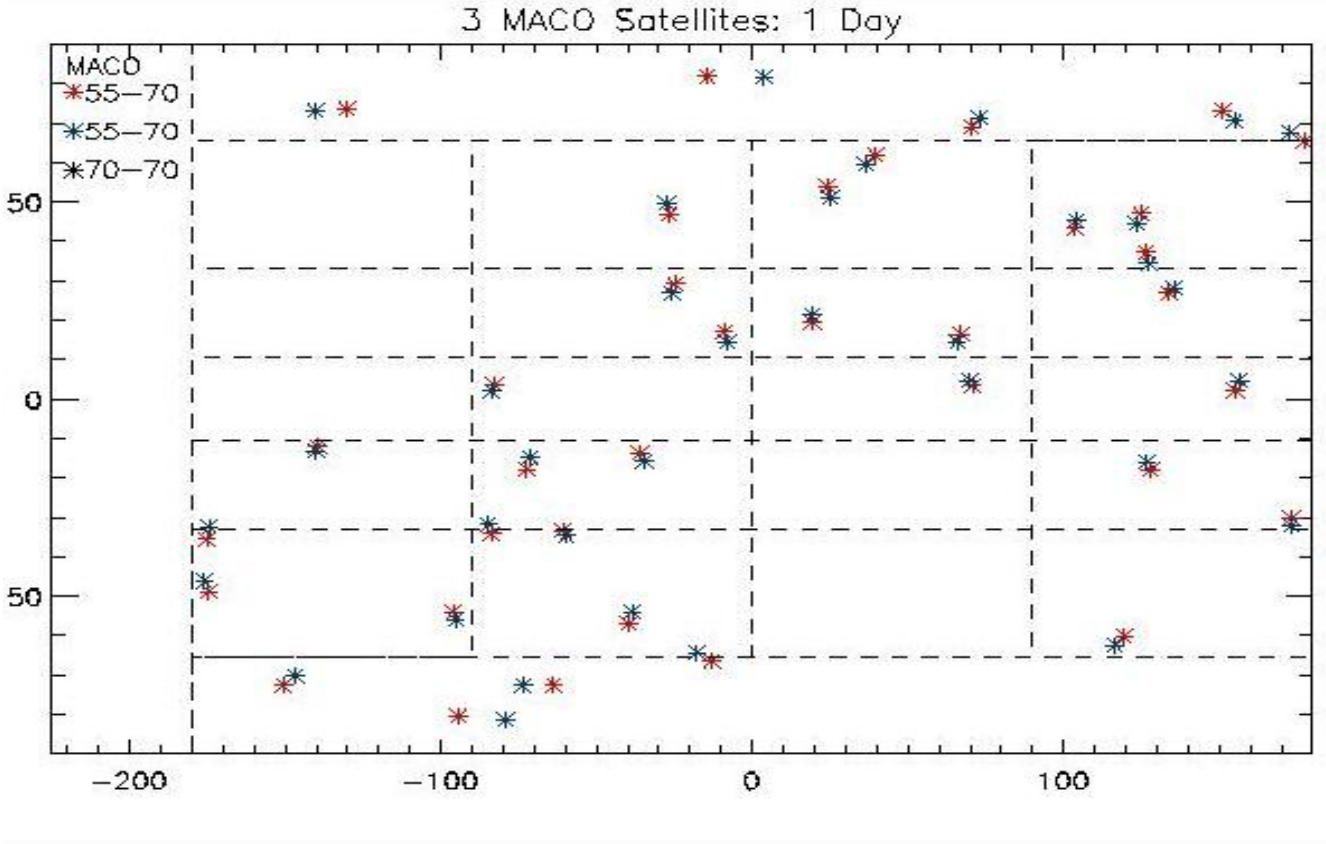
Satellite coverage to measure winds

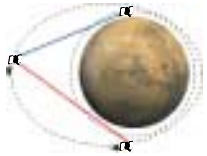
- **Low-level balanced winds will be derived from pressure gradients via differenced occultation pressure profiles**
  - **Yields 1-2 m/s measurement accuracy**
  - **With high vertical resolution**
  - **To near the surface**
  - **Requires occultation profiles spaced closely in space and time**
- **Three satellites offer substantial improvement over two**
  - **With 2 satellites, time separation between spatially close profiles is 12, 24… hours apart**
  - **Therefore diurnal and synoptic scale changes in pressure field alias into pressure gradient estimates**
- **Three-satellite mission can distinguish between mean transport and eddy transport**

=>Wind objectives can be accomplished with 2 satellites + beacon

Wind Coverage using Beacon Satellite

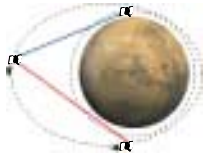
- **Beacon satellite would follow one MACO satellite in orbit, yielding occultation profile pairs (with other MACO satellite)**
  - **Occultation pairs will be close in space and time**
  - **Balanced-wind speed will be determined with 1-2 m/s accuracy**





Mission Design using Beacon Satellite

- **Launch three spacecraft (2 full spacecraft + beacon) on Delta 2925H**
- **Two full spacecraft separate from each other after launch**
  - **Beacon remains attached to one of the full spacecraft**
  - **Cruise independently to Mars**
- **Perform Mars orbit insertion into 24-48 hour period**
  - **Aerobrake into operational orbits**
    - **~2 hour period, altitude of 400-700 km**
- **Deploy beacon satellite,**
  - **Beacon satellite trails (or leads) one of the two full satellites in same orbit**



Summary

- **Satellite to satellite microwave occultation missions provide powerful method of characterizing planetary atmospheres**
  - **Global coverage and unprecedented diurnal coverage**
  - **Very high accuracy and vertical resolution**
- **Beacon satellites can significantly increase coverage of occultation missions**
  - **Adding single beacon to 2 satellite mission**
    - **Doubles or triples coverage**
    - **dramatically improves wind and flux estimates**
- **Beacons offer significant increase in science for very little cost**